DESCRIPTION

OIL PUMP AND AUTOMATIC TRANSMISSION INCLUDING THE SAME

Technical Field

The present invention relates to oil pumps suitable for supplying working oil to automatic transmissions in such as automobiles.

Art

An oil pump of an automatic transmission for a vehicle capable of regulating cavitation erosion is disclosed in Japanese Patent Application Publication No. 2003-161269. According to embodiments, this oil pump includes a cast-iron pump body having a circular hollow portion on an end face thereof; a light-alloy pump cover connected to the end face of the pump body so as to cover the hollow portion and to form a gear compartment therebetween; a driving gear supported and driven by a driving shaft journaled in the pump body in the gear compartment; a driven gear disposed in the gear compartment so as to be rotatable eccentrically to the driving gear and driven by the driving gear that meshes with the driven gear; an arc suction port adjacent to the body and an arc discharge port adjacent to the body formed in the bottom of the hollow portion of the pump body in a suction area and a discharge area, respectively, of working

spaces in the circumferential direction, the working spaces formed by the engagement of these gears; and an arc suction port adjacent to the cover and an arc discharge port adjacent to the cover formed in the inner end face of the pump cover in the suction area and the discharge area, respectively, of the working spaces in the circumferential direction.

With the oil pump according to the technology disclosed in Japanese Unexamined Patent Application Publication No. 2003-161269 (hereinafter simply referred to as the known technology), cavitation erosion can be regulated as expected when the rotational speed of the driving gear is in a normal range of use (for example, up to 7,000 rpm). However, when the rotational speed of the driving gear is higher than that (for example, 7,500 rpm), the cavitation erosion disadvantageously occurs adjacent to the pump cover. This problem will now be described with reference to Figs. 6 and 7.

In the oil pump according to the known technology, a notch 5a adjacent to the body is formed in the bottom of a hollow portion of a pump body 1 (See also a pump body 10 and a hollow portion 11 in Fig. 1), and extends from the front end of a discharge port 4a adjacent to the body in the circumferential direction to the rear end of a suction port 3a adjacent to the body in the circumferential direction in

a suction area of working spaces. In addition, a notch 5b adjacent to the cover shorter than the notch 5a adjacent to the body is formed in the inner end face of a pump cover 2, and extends from the front end of a discharge port 4b adjacent to the cover in the circumferential direction to the rear end of a suction port 3b adjacent to the cover. When a driving gear 6a and a driven gear 6b are rotated in a direction of an arrow during the rotation of the oil pump, working spaces R formed between both the gears 6a and 6b firstly communicate with the discharge port 4a adjacent to the body through the notch 5a adjacent to the body. Since the working spaces R communicate with the suction ports 3a and 3b until immediately before, the working spaces R are filled with low-pressure working oil including bubbles composed of gas of the working oil and air released from the working oil. In contrast, the pressure of the working oil in the discharge ports 4a and 4b is high. When the working spaces R communicate with the notch 5a adjacent to the body, the high-pressure working oil in the discharge port 4a adjacent to the body temporally flows back from the communicating portion adjacent to the pump body 1 toward the inner end face of the pump cover 2 at the opposite side into the working spaces R as indicated by an arrow f. Thus, the bubbles in the working spaces R are crushed, and the impact pressure occurring depending on the crush causes cavitation

erosion at the inner end face in the vicinity where the bubbles are crushed.

When the rotational speed of the oil pump is less than or equal to a predetermined limit, a small number of bubbles in the working spaces R are present. The pressure of the working oil in the discharge ports 4a and 4b is also not very high, and the inflow rate into the working spaces R is also low. Therefore, the crush of the bubbles mainly occurs adjacent to the bottom of the pump body 1, but the crush is not relatively noticeable. Thus, cavitation erosion adjacent to the pump body 1 can be prevented due to the pump body 1 composed of a material such as cast iron having high resistance to cavitation erosion. Accordingly, the above-described known technology is effective in preventing cavitation erosion when the rotational speed of the oil pump is less than or equal to the predetermined limit.

When the rotational speed of the oil pump, however, exceeds the predetermined limit, the pressure in the working spaces R is reduced. Then, the bubbles are increased, and easily accumulated adjacent to the inner circumference due to the increased centrifugal force. Moreover, the pressure of the working oil in the discharge ports 4a and 4b is increased, and the inflow rate into the working spaces R is also increased. Accordingly, the position where the crush of the bubbles occurs is shifted adjacent to the inner end

face of the pump cover 2, and more bubbles are crushed. Since the pump cover 2 is composed of a material such as aluminum having low resistance to cavitation erosion, cavitation erosion occurs at a position indicated by a symbol E1 in the inner end face of the pump cover 2, as shown in Fig. 7(b). Thus, gaps are formed between the pump gears 6a and 6b, and pump efficiency is reduced due to leaking of the working oil. It is believed that cavitation erosion occurs adjacent to the pump cover 2 by the above-described action when the rotational speed of the oil pump exceeds the predetermined limit.

To solve this problem, a possible solution is to provide a pump cover 2 composed of a metallic material having high resistance to cavitation erosion. In this case, aluminum with, for example, T6 heat treatment to increase the surface strength or high-silicon aluminum alloy does not always solve the problem since many bubbles generated in the working spaces R by cavitation are crushed, and therefore, a material such as cast iron having high resistance to cavitation erosion is required. In such a case, the weight of the oil pump is disadvantageously increased since both the pump body 1 and the pump cover 2 are composed of cast iron. When such an oil pump is installed in an automatic transmission for a vehicle, the pump body or the pump cover of the oil pump cannot be integrated with the transmission

housing composed of a light alloy, resulting in a complicated structure.

Disclosure of Invention

To solve the above-described problem, the main object of the present invention is to provide an oil pump capable of surely regulating the cavitation erosion during high-speed rotation of the driving gears even when the pump cover is composed of a conventional light alloy.

According to the present invention, the above-described object can be achieved by an oil pump including a pump body having a hollow portion on an end face thereof; a pump cover, the inner end face of the pump cover connected to the end face of the pump body so as to cover the hollow portion and to form a gear compartment therebetween; a driving gear driven by a driving shaft in the gear compartment; a rotatable driven gear disposed in the gear compartment and driven by the driving gear that meshes with the driven gear; a discharge port adjacent to the body and a discharge port adjacent to the cover formed in the bottom of the hollow portion of the pump body and the inner end face of the pump cover, respectively, in a discharge area of working spaces formed by the engagement of the driving gear and the driven gear; a notch adjacent to the body extending from the front end of the discharge port adjacent to the body to the rear

end of the discharge area of the working spaces at the bottom of the hollow portion of the pump body; and a notch adjacent to the cover extending from the front end of the discharge port adjacent to the cover to the rear end of the discharge area of the working spaces at the inner end face of the pump cover, one of the pump body and the pump cover composed of cast iron and the other composed of a light alloy, characterized in that the length of the notch formed in the pump body or the pump cover composed of the light alloy is longer than that of the notch formed in the pump body or the pump cover composed of the cast iron; and bubbles generated in working oil in the working spaces during the high-speed rotation of the driving gear are crushed by the high-pressure working oil flowing back to the working spaces through the longer notch adjacent to the inner surface of the pump body or the pump cover composed of the cast iron facing the working spaces.

According to the oil pump of the present invention, it is preferable that the driven gear be a rotatable internal gear having the outer circumference supported by the inner circumference of the gear compartment; the driving gear be an external gear meshing with the driven gear; the discharge port adjacent to the body and the discharge port adjacent to the cover be each arc; and the notch adjacent to the body and the notch adjacent to the cover extend from the front

ends of the discharge port adjacent to the body and the discharge port adjacent to the cover, respectively, in the circumference direction to the rear end of the discharge area of the working spaces.

According to the oil pump of the present invention, it is preferable that the notch formed in the pump body or the pump cover composed of the light alloy have an approximately triangular shape and a width decreasing from the front end of the discharge port adjacent to the cover toward the rear end of the discharge area of the working spaces.

Moreover, according to the oil pump of the present invention, it is preferable that the notch formed in the pump body or the pump cover composed of the light alloy have an inclined bottom so as to reduce the depth from the front end of the discharge port adjacent to the cover toward the rear end of the discharge area of the working spaces.

Furthermore, the automatic transmission according to the present invention is characterized in that the supply source of the hydraulic pressure is the oil pump according to the present invention, and the pump body or the pump cover composed of the light alloy is integrated with a housing of the automatic transmission.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view of an oil pump

according to an embodiment of the present invention;

Fig. 2 is a cross-sectional view taken along line 2 - 2 in Fig. 1;

Fig. 3 is a cross-sectional view taken along line 3 - 3 in Fig. 2;

Figs. 4(a) and 4(b) illustrate the arrangement of ports and notches according to the embodiment shown in Fig. 1, Fig. 4(a) illustrates part of the bottom of a hollow portion of a pump body, and Fig. 4(b) illustrates part of an inner end face of a pump cover;

Fig. 5 illustrates the relationship between rotational angles of pump gears and open cross-sectional areas between working spaces and discharge ports according to the embodiment shown in Fig. 1;

Fig. 6 is a cross-sectional view of an oil pump corresponding to Fig. 2 according to the known technology; and

Figs. 7(a) and 7(b) are partial views of the oil pump corresponding to Figs. 4(a) and 4(b) according to the known technology.

Best Mode for Carrying Out the Invention

An oil pump according to an embodiment of the present invention will now be described with reference to Figs. 1 to 5. The oil pump according to the embodiment supplies

working oil to an automatic transmission for a vehicle such as an automobile; and includes a housing H consisting of a pump body 10 and a pump cover 15 connected to each other, and pump gears consisting of a driving gear 30 and a driven gear 31 accommodated in the housing H so as to be rotatable. The pump cover 15 is integrated with a housing of an automatic transmission for an automobile.

The pump body 10 is composed of a metallic material such as cast iron having high resistance to cavitation erosion. With reference to Fig. 1, a circular hollow portion 11 with a predetermined shallow depth accommodating the pump gears 30 and 31 so as to be rotatable is formed in a flat side face of the pump body 10, and a center hole 12 passing through the pump body 10 is formed at the bottom of the hollow portion 11 so as to be decentered from the center of the hollow portion 11 by a distance equal to that between the pump gears 30 and 31. The pump cover 15 is composed of a light alloy such as aluminum having resistance to cavitation erosion lower than that of the pump body 10. The pump cover 15 is bolted to the pump body 10 such that a flat side face thereof hermetically covers the hollow portion 11. Thus, a gear compartment G accommodating the pair of pump gears 30 and 31 is formed between the pump body 10 and the pump cover 15. A tubular stator shaft 17 is pressed into a center hole 16 formed in the pump cover 15 coaxially to the

center hole 12 of the pump body 10, and passes through the pump body 10 so as to be remote from the center hole 12 with a space. A tubular driving shaft 13 is fitted into a space between the stator shaft 17 and the center hole 12, and is supported by a rotatable bearing bush 12a fixed to the inner face of the center hole 12. A space between the driving shaft 13 and the pump body 10 is sealed by an oil seal 14.

The external driving gear 30 and the internal driven gear 31 having one more additional tooth than the driving gear 30 have the same thickness, and have trochoidal teeth meshed with each other. Both the side faces of these gears are remote from both the inner faces of the gear compartment formed by the pump body 10 and the pump cover 15 with sufficiently small gaps such that working oil substantially does not leak from the gaps, and are slidable and rotatable relative to the inner faces of the gear compartment. The driving gear 30 is supported by fitting the inner circumference thereof to the outer circumference of an end of the driving shaft 13, and a pair of keys 30a protruding from the inner circumference is caught by keyways formed in the end of the driving shaft 13 such that the driving gear 30 is rotatable. The outer circumference of the driven gear 31 is supported by the inner circumference of the hollow portion 11 so as to be rotatable.

As mainly shown in Fig. 2, a large number of working

spaces R are formed between each tooth of the pump gears 30 and 31 accommodated in the gear compartment G and meshing with each other. While the pump gears 30 and 31 are rotated, the working spaces R move along an annular space formed between the root circles of the pump gears 30 and 31, and each volume of the working spaces R is increased and decreased. A suction area where the volumes of the working spaces R are gradually increased during the rotation of the pump gears 30 and 31 is formed in a range of 180° from a contact position of pitch lines of the pump gears 30 and 31 in the rotational direction of the pump gears 30 and 31, and a discharge area where the volumes of the working spaces R are gradually decreased during the rotation of the pump gears 30 and 31 is formed in a range of 180° from the contact position of the pitch lines of the pump gears 30 and 31 in the opposite direction to the rotational direction.

As shown in Figs. 1 and 2, a suction port 20a adjacent to the body and a suction port 20b adjacent to the cover opposing each other are formed in the bottom of the hollow portion 11 of the pump body 10 and in the inner end face of the pump cover 15 opposing the bottom of the hollow portion 11, respectively, and range in considerable areas corresponding to the suction area except for both ends. Openings of the suction ports 20a and 20b are arc, and the shapes and the areas are equal. The inner ends and the

outer ends of the suction ports 20a and 20b correspond to the root circles of the pump gears 30 and 31, respectively. The suction ports 20a and 20b communicate with suction channels 21 formed in the pump body 10 and the pump cover 15 and introducing the working oil from a reservoir (not shown).

Moreover, a discharge port 25a adjacent to the body and a discharge port 25b adjacent to the cover opposing each other are formed in the bottom of the hollow portion 11 of the pump body 10 and in the inner end face of the pump cover 15 opposing the bottom of the hollow portion 11, respectively, and range in considerable areas corresponding to the discharge area except for both ends. Openings of the discharge ports 25a and 25b are arc, and the shapes and the areas are equal. The inner ends and the outer ends of the discharge ports 25a and 25b correspond to the root circles of the pump gears 30 and 31, respectively. A slope 25a1 having a depth decreasing toward the front end in the rotational direction where the communication with the moving working spaces R starts is formed in part of the bottom of the discharge port 25a adjacent to the body. The discharge port 25a adjacent to the body communicates with a discharge channel 27 formed in the pump body 10 and the pump cover 15 and supplying the working oil to a destination. On the other hand, the discharge port 25b adjacent to the cover is made shallower than the discharge port 25a adjacent to the

body so as to avoid a fluid channel (not shown) formed in the pump cover 15, and does not communicate with the discharge channel 27.

As shown in Figs. 1 to 4, a notch 26a adjacent to the body communicating with the discharge port 25a adjacent to the body and a notch 26b adjacent to the cover communicating with the discharge port 25b adjacent to the cover are formed in the bottom of the hollow portion 11 of the pump body 10 and in the inner end face of the pump cover 15 opposing the bottom of the hollow portion 11, respectively. The notches 26a and 26b extend from the front ends of the discharge ports 25a and 25b in the rotational direction along the circumferential direction to the rear ends of the suction ports 20a and 20b in the rotational direction along the circumferential direction, respectively. The notch 26b adjacent to the cover is longer than the notch 26a adjacent to the body. The length of the longer notch 26b adjacent to the cover is a fraction (for example, 1/4) of the distance between the rear ends of the suction ports 20a and 20b in the rotational direction and the front ends of the discharge ports 25a and 25b in the rotational direction. The length of the shorter notch 26a adjacent to the body is approximately half to quarter of that of the notch 26b adjacent to the cover. In this embodiment, as shown in Figs. 2 to 4, the notch 26b adjacent to the cover has an

approximately triangular shape and a width decreasing from the front end of the discharge port 25b adjacent to the cover in the rotational direction toward the rear end of the suction port 20b adjacent to the cover in the rotational direction when viewed from the pump body 10. Also, the bottom of the notch 26b adjacent to the cover is inclined so as to reduce the depth from the front end of the discharge port 25b adjacent to the cover in the rotational direction toward the rear end of the suction port 20b adjacent to the cover in the rotational direction.

In Fig. 2, during the operation of the oil pump according to this embodiment, the pump gears 30 and 31 are rotated by the driving shaft 13 in a direction of an arrow, i.e. counterclockwise, and the working spaces R are rotated in the same direction while the volumes thereof are changed. In Fig. 3, the pump gears 30 and 31 and the working spaces R are moved leftward as indicated by an arrow. As a result, the working oil in the reservoir passes through the suction channels 21, is sucked from both the suction ports 20a and 20b into the working spaces R in the suction area, is discharged from the working spaces R in the discharge area to the discharge ports 25a and 25b, and is supplied to the destination through the discharge channel 27.

Since the pressure of the working oil in the suction area is negative, the working oil sucked from the suction

ports 20a and 20b into the working spaces R includes bubbles. The working spaces R sucking the working oil move according to the rotation of the pump gears 30 and 31, and are shut in the space between the rear ends of the suction ports 20a and 20b in the rotational direction and the front ends of the discharge ports 25a and 25b in the rotational direction and between the bottom of the hollow portion 11 and the inner end face of the pump cover 15. As shown in Fig. 3, when the tips of the working spaces R further move and pass a first release point P1 (See Fig. 5) being the tip of the notch 26b adjacent to the cover, the working spaces R communicate with the discharge port 25b adjacent to the cover through the tip of the notch 26b adjacent to the cover. Furthermore, when the tips of the working spaces R pass a second release point P2 being the tip of the notch 26a adjacent to the body, the working spaces R communicate with the discharge port 25a adjacent to the body through the tip of the notch 26a adjacent to the body in addition to the notch 26b adjacent to the cover. Finally, when the tips of the working spaces R pass a third release point P3 being the front ends of the discharge ports 25a and 25b in the rotational direction, the working spaces R directly communicate with the discharge ports 25a and 25b. Accordingly, open cross-sectional areas between the working spaces R and the discharge ports 25a and 25b that are filled with the working oil shut in the space

between the bottom of the hollow portion 11 and the inner end face of the pump cover 15 and including bubbles due to the low pressure are acceleratingly and continuously increased depending on rotational angles of the pump gears 30 and 31 as indicated by the solid line shown in Fig. 5.

As shown in Fig. 3, when the tips of the working spaces R that were shut in the space between the bottom of the hollow portion 11 and the inner end face of the pump cover 15 pass the first release point P1 so as to communicate with the discharge port 25b adjacent to the cover through the tip of the notch 26b adjacent to the cover, the high-pressure working oil in the discharge port 25b adjacent to the cover temporally flows back from the communicating portion adjacent to the pump cover 15 into the working spaces R as indicated by an arrow F. Thus, the pressure in the working spaces R is increased, and the bubbles therein are crushed. While the pump gears 30 and 31 are rotated after the communication starts, the opening area of the longer notch 26b adjacent to the cover is increased relative to the working spaces R. According to this, an inflow rate of the working oil from the discharge port 25b adjacent to the cover into the working spaces R is reduced, and therefore, fewer bubbles in the working spaces R are crushed. When the shorter notch 26a adjacent to the body communicates with the working spaces R, the inflow rate into the working spaces R

is further reduced, and still fewer bubbles in the working spaces R are crushed.

When the rotational speed of the oil pump is less than or equal to a predetermined limit (for example 7,000 rpm), a small number of bubbles in the working spaces R are present, and the pressure of the working oil in the discharge ports 25a and 25b are also not very high. In addition, the inflow rate of the working fluid that flows from the notch 26b adjacent to the cover toward the bottom of the hollow portion 11 of the pump body 10 at the opposite side into the working spaces R as indicated by the arrow F in the state shown in Fig. 3 is low. Thus, the crush of the bubbles mainly occurs adjacent to the inner end face of the pump cover 15, but the crush is not relatively noticeable. Therefore, if the pump cover 15 is composed of a material such as aluminum having low resistance to cavitation erosion, the small cavitation erosion that occurs in the inner end face is substantially insignificant. As described above, while the pump gears 30 and 31 are rotated after the communication starts, the inflow rate of the working oil from the discharge port 25b adjacent to the cover into the working spaces R is reduced, and therefore, the cavitation erosion that occurs in the inner end face of the pump cover 15 is further regulated.

When the rotational speed of the oil pump exceeds the

predetermined limit (for example 7,500 rpm), the pressure in the working spaces R is reduced. Then, the bubbles are increased, and are accumulated adjacent to the inner circumference of the working spaces R due to the centrifugal force. Moreover, the pressure of the working oil in the discharge ports 25a and 25b are increased, and the inflow rate of the working fluid that flows toward the bottom of the hollow portion 11 of the pump body 10 into the working spaces R as indicated by the arrow F is also increased. Accordingly, the position where the crush of the bubbles occurs is shifted adjacent to the bottom of the hollow portion 11 in the working spaces R, and also, more bubbles are crushed. However, the pump body 10 is composed of a material such as cast iron having high resistance to cavitation erosion, the cavitation erosion does not occur at the bottom of the hollow portion 11 of the pump body 10. In addition, as described above, while the pump gears 30 and 31 are rotated after the communication starts, the opening area of the notch 26b adjacent to the cover is increased, the shorter notch 26a adjacent to the body communicates with the working spaces R, and therefore, the position where the crush of the bubbles occurs is shifted adjacent to the inner end face of the pump cover 15. However, since the inflow rate of the working oil from the notches 26a and 26b into the working spaces R is reduced, the cavitation erosion is

regulated.

In the above-described embodiment, the notch 26b adjacent to the cover has an approximately triangular shape and a width decreasing from the front end of the discharge port 25b adjacent to the cover in the rotational direction toward the suction port 20b adjacent to the cover, and also, the bottom of the notch 26b adjacent to the cover is inclined so as to reduce the depth. With this structure, the opening area of the notch 26b adjacent to the cover relative to the working spaces R is immediately increased in response to the rotation of the pump gears 30 and 31, the inflow rate of the working oil from the notch 26b adjacent to the cover into the working spaces R is immediately reduced, and therefore, the crush of the bubbles is also immediately reduced. Accordingly, when the rotational speed of the oil pump is less than or equal to a predetermined limit, the small cavitation erosion that occurs in the inner end face of the pump cover 15 is further reduced. However, the present invention is not limited to that described above. The notch 26b adjacent to the cover may have a predetermined width and length as in the case of a notch 5a adjacent to the body according to the known technology shown in Figs. 6 and 7. In varying degrees, the cavitation erosion can be regulated as described above, and the effect is sufficient in some cases.

Furthermore, in the above-described embodiment, the driven gear 31 is a rotatable internal gear having the outer circumference supported by the inner circumference of the gear compartment G, and the driving gear 30 is an external gear that meshes with the driven gear 31. With this structure, the driving gear 30 can be accommodated in the driven gear 31 so as to reduce the volume of the pump gears 30 and 31, and a small oil pump can be produced. However, the present invention is not limited to that described above, and both the pump gears may be of an external type. In this case, the hollow portion may have a shape consisting of two circles overlapped at the rims.

The oil pump according to the above-described embodiment supplies working oil to an automatic transmission for a vehicle. Since the pump cover 15 is composed of a light alloy having low resistance to the cavitation erosion, the pump cover 15 can be integrated with the transmission housing composed of the light alloy such as aluminum. As a result, the structure of the automatic transmission with the oil pump can be simplified. However, the application of the oil pump according to the present invention is not limited to that described above. The oil pump is available as a supply source of the working oil used in various devices such as infinitely variable transmissions for vehicles. Also, the pump body may be composed of aluminum or the like

having low resistance to the cavitation erosion, and the pump cover may be composed of cast iron or the like having high resistance to the cavitation erosion depending on the applications and the circumstances. In this case, the length of a notch formed in the pump body composed of aluminum or the like may be made larger than that of a notch formed in the pump cover composed of cast iron or the like.